

## **1.0 PROJECT BACKGROUND, OBJECTIVES AND OVERVIEW**

### **1.1 PROJECT BACKGROUND**

The Everglades Forever Act (EFA), Section 373.4592, Florida Statutes, enacted by the Florida Legislature in May 1994, mandates a series of State agency actions to restore the Everglades. The restoration projects mandated by the EFA include research, regulation, exotic species control and construction projects; they are collectively referred to as the Everglades Program. As part of the Everglades Program, the EFA requires the South Florida Water Management District (SFWMD) to design and build six stormwater treatment areas (STAs) to remove phosphorus from Everglades Agricultural Area (EAA) stormwater runoff before releasing to the Everglades Protection Area (EPA). STAs are constructed wetlands that will provide water quality treatment through natural biological and physical processes. STAs will encompass approximately 46,000 acres, and are being designed to treat more than one million acre-feet per year of water received from the EAA and Lake Okeechobee. STAs will be used in combination with on-farm Best Management Practices (BMPs) to reduce phosphorus concentrations to within the Everglades Program Phase I goal of 50 µg/L.

The EFA also requires SFWMD and the Florida Department of Environmental Protection (FDEP) to conduct research and rulemaking to interpret numerically the existing narrative Class III water quality standard for phosphorus. A comprehensive research program that determines the maximum phosphorus concentration that will not cause an imbalance in the natural flora or fauna of the Everglades is ongoing and targeted for completion by no later than January 1, 2001. Preliminary results from research and modeling indicate that the threshold phosphorus concentration will be below the 50 µg/L goal expected from the Phase I STAs.

Phase II of the Everglades Program involves the implementation of new basin-scale treatment processes (also referred to as "advanced technologies"), as stand-alone treatment systems or in series with STAs, to reduce phosphorus concentrations to within the threshold concentration. Because the threshold phosphorus concentration is expected to be less than the Phase I goal of 50 µg/L and because the EFA establishes a default phosphorus criterion of 10 µg/L if FDEP does not adopt a final Total Phosphorus (Total P) criterion by December 31, 2003, Phase II of the Everglades Program is focused on demonstrating water quality treatment technologies capable of reducing phosphorus concentrations to approximately 10 µg/L. Treatment technologies that can meet or surpass the Phase II goal will allow the default phosphorus criterion to be met with the

most appropriately sized system. The EFA requires SFWMD to have treatment technologies on-line by December 31, 2006.

The advanced technologies must be demonstrated sufficiently to establish their technical, economic and environmental feasibility for basin scale application. Furthermore, the treatment may supplement the STAs as part of a treatment train, to meet the interim (default) phosphorus concentration limit of 10 µg/L, unless a future alternate limit is negotiated. The EFA specifies that the evaluation process must address an initial set of technology criteria, which are set forth below:

- Technical feasibility;
- Levels of load reduction;
- Levels of discharge concentration reduction;
- Water quantity, distribution and timing for the EPA;
- Compliance with water quality standards;
- Compatibility of treated water with the balance in natural populations of aquatic flora and fauna in the EPA (*i.e.*, marsh readiness of effluents);
- Environmental acceptability;
- Cost effectiveness; and
- Schedule for implementation.

Based on an extensive series of evaluations of numerous alternative water treatment technologies performed by Brown and Caldwell (B&C, 1992, 1993 and 1996) under previous contracts with SFWMD, one of the most promising basin-scale processes for application in the EAA is chemical treatment followed by solids separation (CTSS). The specific CTSS processes identified by B&C include direct filtration, high-rate settling and dissolved air flotation. CTSS offers the potential advantages of low land requirement, flexibility, reliability, and ability to reduce phosphorus to levels substantially lower than could be achieved using STAs alone. This project will demonstrate CTSS as a potential technology for meeting the Phase II phosphorus reduction goals. Before implementing CTSS as a basin-scale treatment process, the technology must be demonstrated sufficiently to establish its technical feasibility, economic viability, and environmental compatibility.

The United States Environmental Protection Agency (USEPA) is cost-sharing a portion of the CTSS project through its Section 319h grant program, which is being administered by the FDEP. All deliverable requirements of the Section 319h grant will be incorporated as part of this CTSS project. Final deliverables from this project will be

shared with members of the Section 319h project team, including the USEPA, the United States Army Corps of Engineers and the Florida Department of Agriculture and Consumer Services.

## **1.2 PROJECT OBJECTIVES**

The primary objective of this project was to evaluate - for full-scale implementation - the technical, economic and environmental feasibility of the CTSS technology. The specific objectives of the operations were to:

- Identify and demonstrate an optimized CTSS process, for which operating conditions can be described and full-scale costs projected;
- Conduct sampling adequate to complete a Supplemental Technology Standard of Comparison (STSOC) evaluation as described by PEER Consultants/Brown and Caldwell Joint Venture; and,
- Develop process criteria and experience needed to design a full-scale CTSS system.

CTSS pilot testing was used to determine the ability of chemical coagulation coupled with solids separation techniques (*e.g.*, solids settling/clarification and filtration) to remove Total P from representative Post-BMP and Post-STA canal surface waters within the EAA. The optimum CTSS treatment process will produce the lowest possible effluent Total P at the lowest capital and operating cost and have a benign environmental impact on downstream marshes and wetlands.

## **1.3 PROJECT OVERVIEW**

The CTSS project evaluated the feasibility of using the technology (chemical treatment followed by high rate settling and/or filtration) as a basin-scale treatment process for reducing phosphorus loads from the EAA. The chemical treatment phase of CTSS involves the use of metal (iron or aluminum) salts to precipitate dissolved phosphorus. These metal salts are routinely used in conventional water treatment facilities for producing drinking water. Metal salts also coagulate the precipitates and other particles, which allows small particulates to be coalesced (flocculated) into larger and more readily settled or readily filtered agglomerates. The precipitation and coagulation reactions are pH dependent, and acids and bases were also tested in combination with the metallic salts to vary pH within the desired ranges. Organic polymers were used to increase flocculent

size, density, and strength. The polymers employed all met National Sanitary Foundation (NSF) Standard 61 for use in drinking water applications. Solids generated from the coagulation and flocculation process were then separated from the liquid through settling and/or filtration.

The CTSS Pilot Unit facility was initially located at the southern end of the Everglades Nutrient Removal (ENR) Project. The ENR is a prototype, constructed wetlands developed to determine the effectiveness of filter marshes/wetland systems to reduce the phosphorus content of the EAA surface waters. The pilot unit had been established adjacent to the ENR exit canal to test Post-STA surface waters. **FIGURE 1.1** shows a map of the EAA and provides the location of the ENR.

The CTSS test facility consisted of two process trains, each containing the following equipment:

- One cubic meter mix tank complete with a mechanical mixer for rapid/flash mixing;
- Two 1-cubic meter flocculation tanks fitted with variable speed mechanical flocculating blades;
- One clarifier with a variable hydraulic capacity up to approximately 30 gallons per minute;
- One backwash tank for retaining an entire volume of backwash solids and water;
- Flow meters, sensors and composite samplers sufficient to measure the quantity and quality of feed, effluent and intermediate points throughout the pilot facility; and
- A total of nine 8-inch diameter dual and triple media filter columns. All of the columns were 10 feet in height: 6 columns for filtration and 3 columns for adsorption (adsorption columns were tested on Post-BMP waters only).

**FIGURE 1.2** provides a schematic diagram of the CTSS pilot facility. Further details on the pilot facility are provided in Section 2.

Operational variables that were screened and optimized included feed flow rates, flocculation retention times and mixing speeds, coagulant feed concentrations, clarifier overflow rates, sludge recirculation rate, filter media composition and filtration rates. Some tests included all of the process units listed above in series and others limited the treatment train to selected units. For example, direct filtration tests were conducted using only the flocculation tanks with these flows being sent directly to the filtration columns, bypassing the clarifier.

After numerous screening tests were conducted on ENR effluent (Post-STA) waters and the more effective testing options had been identified, a modified pilot test facility was installed to test representative Post-BMP canal surface waters. The Post-BMP testing was conducted at the ENR North Test Site.

The CTSS demonstration project field testing was conducted in six stages over a period of seven months:

<b><u>Stage</u></b>	<b><u>Duration</u></b>	<b><u>Dates (1999)</u></b>
1 - Shakedown	2 weeks	May 10 – May 24
2 - Pre-Screening	2 weeks	May 17 – June 1
3 - Screening	17 weeks	June 2 – Sept. 25
4 - Optimization Level 1	4 weeks	Oct. 26 – Nov. 15
5 - Optimization Level 2	3 weeks	Nov. 16 – Dec. 3
6 - Demonstration	4 weeks	Dec.4 – Dec. 23

*(Note: From September 26 through October 25, the North Site facility was constructed.)*

In addition to the testing conducted on the pilot facilities, several vendor technologies were evaluated including dissolved air flotation, high rate sedimentation, ballasted sand flocculation, as well as others during the May through December testing period. **TABLE 1.1** provides a chronology of the major activities completed during the CTSS project.

This Final Report includes the following for the entire project: 1) an overview of the CTSS system and a discussion of how it was operated; 2) the overall design, 3) a summary of the test data; 4) data analysis and conclusions; 5) a set of recommendations and costs for scaling up the technology from demonstration-scale to full basin-scale treatment; and 6) order of magnitude engineering cost estimate for a full-scale facilities.

## **1.4 TECHNICAL REVIEW TEAM PARTICIPATION**

A Technical Review Team (TRT) was established at the onset of the project and the members included internationally recognized authorities in water treatment technology. TRT members included: Dr. Jack Cleasby (a water treatment filtration expert); Dr. Gary Amy (an environmental engineering professor at the University of Colorado and an authority on the characterization and treatment of natural organic matter [NOM]); Dr. Petr Dolejs (environmental consultant and expert on the interaction of temperature and operation variables on the treatment of humic containing waters); and Dr. Earl Shannon (who served as the chairperson of the TRT and a recognized water treatment and water quality expert). The TRT convened a total of three times during the course of the project and provided valuable guidance at the project onset and throughout the field investigations.

## **1.5 ‘BAYESIAN’ APPROACH TO INVESTIGATION**

Statistical design of scientific investigation was first introduced by Fisher in the 1920s (Ollos, 1998). Factorial tests often involve several variables examined at multiple design levels. The completion of a large number of tests is generally not possible, or at least not practical, due to time and material constraints. The later-developed fractional factorial design technique necessitates a reduced number of test trials, but has the disadvantage of confounding between potentially important main effects and/or interactions. Strictly speaking, (complete or fractional) factorial tests should be designed when nothing is known about a process. In fact, some prior knowledge is almost always available (about everything) which allows design according to a ‘Bayesian’-type of investigation (Reilly, 1993).

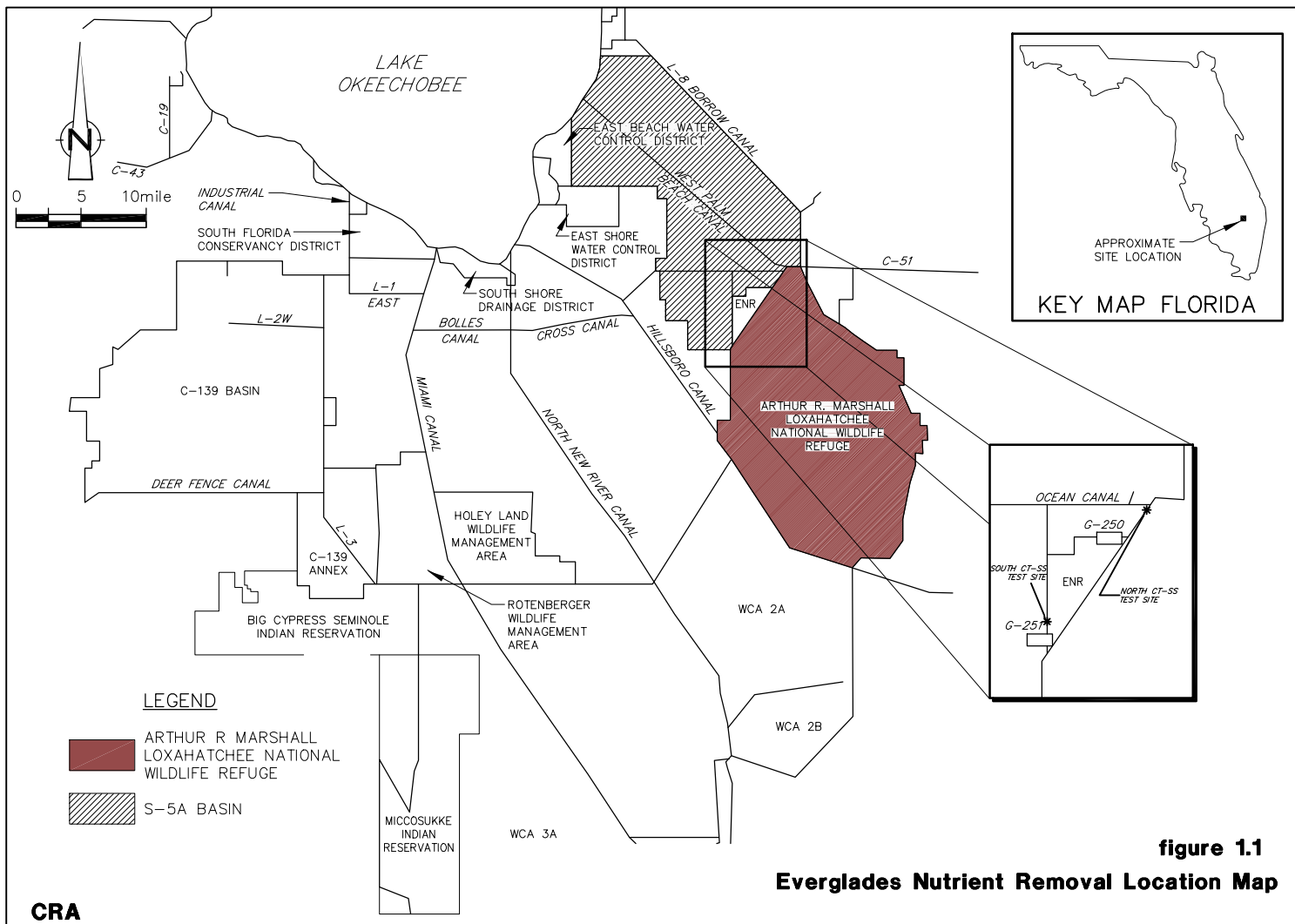
Thomas Bayes developed his famous theorem in the 1750s. After his death in 1761, the ‘Bayesian’ approach to scientific investigation was published in 1762 by his friend, Richard Price. Before a test is performed, the scientist or engineer has a certain level of knowledge about the result, which will be obtained. This knowledge may stem from (1) previous experience in the subject area or (2) from the findings of other researchers. Bayes’ theorem describes in a fundamental way the process of learning from experience. Besides easy management of common problems, such as dropped or altered design levels during the course of testing, the ‘Bayesian’ approach also minimizes testing efforts (*i.e.*, provides the most new information with the least amount of test trials). This is accomplished by the use of a sequential design technique and the typical update of prior covariances (*i.e.*, assumed knowledge) before the design of each new segment. Unlike conventional factorial design, the number of ‘Bayesian’-designed tests is not restricted.

Typically, the variances in a ‘Bayesian’ design are higher than those of a fractional/factorial design test. On the other hand, no complete confounding of the various factors exists in a ‘Bayesian’-designed test. Further details on the mathematical basis of the ‘Bayesian’ approach are provided in **APPENDIX 1.1**.

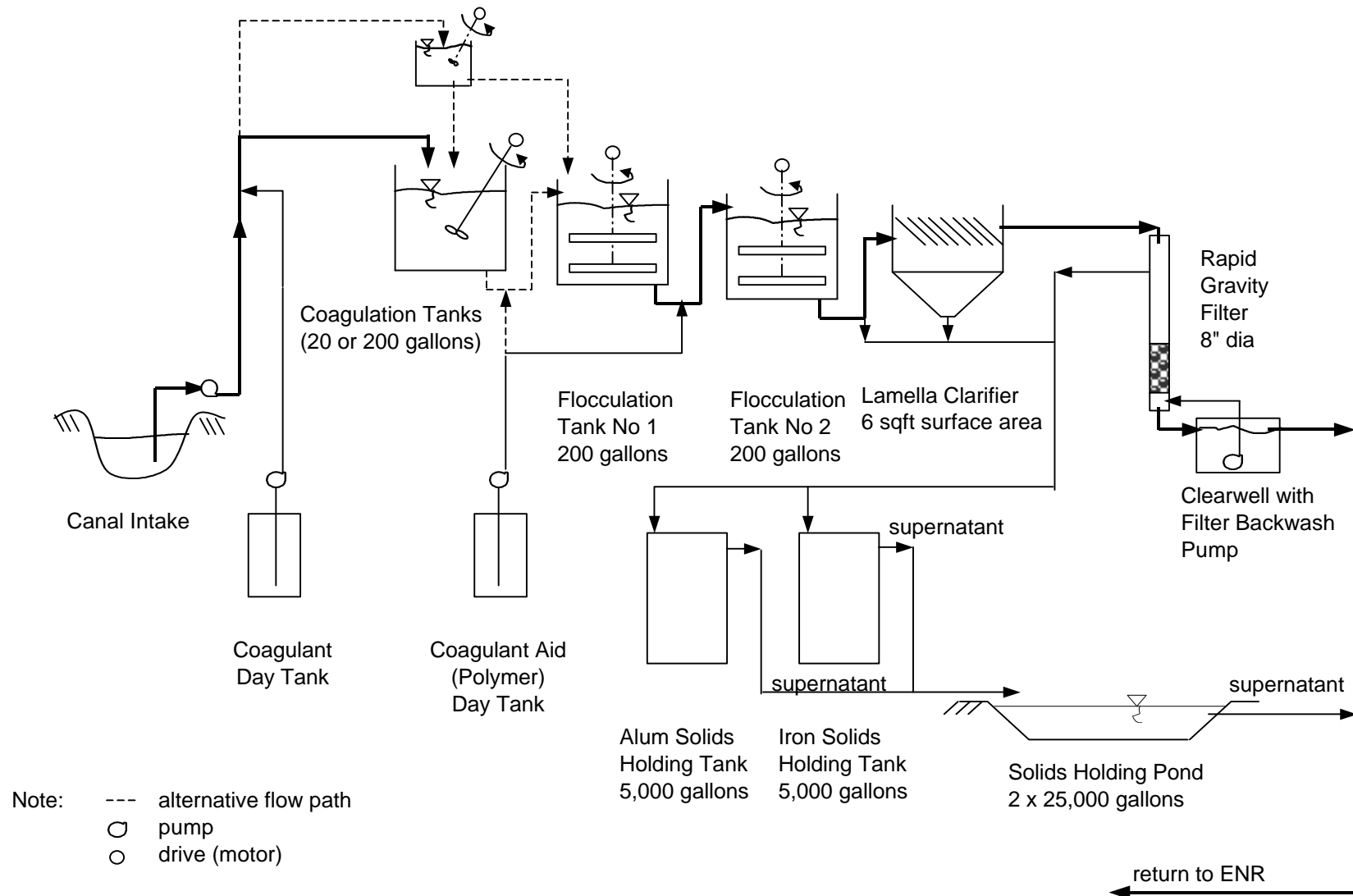
The CTSS project was well suited to using ‘Bayesian’ testing design techniques due to the significant amount of previous jar testing data available for input during model development. The ‘Bayesian’ technique was used to assist the CTSS project team in developing daily test conditions during the course of the field investigations. Actual testing matrices developed showing daily conditions (*e.g.*, chemical type, dosage rates, clarifier overflow rate, etc.) are provided.

## **CHAPTER 1 - REFERENCES**

- Peter J. Ollos, "Effects of Drinking Water Biodegradability and Disinfectant Residual on Bacterial Regrowth," (Ph.D. Dissertation, Department of Civil Engineering, University of Waterloo, Ontario, Canada, 1998).
- Mixing in Coagulation and Flocculation*, American Water Works Association Research Foundation, Denver, Colorado. Edited by A. Amirtharajah, M.M. Clark, and R.R. Trussell (1991).
- Brown and Caldwell Consultants, "Evaluation of Alternative Treatment Technologies – Evaluation Methods and Procedures," Final Report under SFWMD Contract No. C-3051, Amendment 1 (September 25, 1992).
- Brown and Caldwell Consultants, "Phase I Evaluation of Alternative Treatment Technologies," Final Report under Contract No. C-3051, Amendment 2 (January 19, 1993).
- Brown and Caldwell Consultants, "Phase II Evaluation of Alternative Treatment Technologies," Final Report under Contract No. C-3051, Amendment 4 (May 15, 1993).
- PEER Consultants, P.C./Brown and Caldwell Consultants, "Desktop Evaluation of Alternative Technologies," Final Report under SFWMD Contract No. C-E008, Amendment 3 (August 1996).
- Park M. Reilly, "A Bayesian Approach to Experimentation" (University of Waterloo, Ontario, Canada, 1993).



**FIGURE 1.2**  
**Schematic Diagram of CTSS Pilot Facility**



**TABLE 1.1**  
**CTSS Field Activities Chronological Sequence of Events**

1. Event	2. Organization	3. Scope	4. Duration (1999)	
			From:	To:
TRT Meeting #1	Technical Review Team	General directions	May 3	May 3
CTSS Preliminary Phase	HSA	Equipment setup, etc.	May 17	June 2
CTSS Screening Phase	HSA	Assessment of filtration and dosages	June 3	September 25
Jar Testing No. 1	HSA / Dr. Dolejs	Pilot optimization	June 22	June 25
Bench Scale Filtration	University of Florida / HSA	Bench scale filtration with coated granular media	July 6 and September 8	July 6 and September 8
Bench Scale Filtration	Syracuse University, NY / HSA	Bench scale filtration with glass-sand filter media	July 7	July 21
Vendor Testing	Biochem Technologies Inc. / HSA	Dolomitic lime fixed film bio-reactor pilot test	August 3	December 23
Jar Testing No. 2	Etus Inc. / HSA	Jar testing of vendor supplied coagulant aids	August 17	August 17
Jar Testing No. 3	HSA / Dr. Dolejs	Lake Okeechobee settling	August 18	August 23
TRT Meeting #2	Technical Review Team	Screening review and optimization planning	August 20	August 20
Vendor Testing	HSA / Rochem Environmental Inc.	2 gpm Ultrafiltration pilot test	September 14	November 24
Vendor Testing	HSA / Zenon Environmental Inc.	10 gpm Microfiltration pilot test	September 27	November 22
Vendor Testing	F.B. Leopold Company / HSA	Dissolved air flotation pilot test	October 11	October 24
Vendor Testing	HSA / Infilco Degremont Inc.	DensaDeg high rate clarification and thickening pilot test	October 11	December 12
CTSS Optimization Phase	HSA	Process optimization	October 26	December 3
Vendor Testing	Krüger Inc. / HSA	ACTIFLO (ballasted sand) process pilot test	November 7	November 26
Solids Leaching Study	HSA / SFWMD	Phosphorus release	November 11	December 17
Jar Testing No. 4	HSA / Dr. Dolejs	Lake Okeechobee discharges settling	November 19	November 24
TRT Meeting #3	Conference Call	Technical Review Team – Confirm demonstration conditions	November 18	November 18 (2 hours)
Vendor Testing	MicroMag Corporation / HSA	CoMag process pilot test	November 28	December 21
CTSS Demonstration Phase	HSA	Demonstration of process performance	December 4	December 23
Pilot Scale Filtration	HSA	Activated alumina filter media test	December 17	December 22